Let’s Talk Water – Isotopes

By Dr. Mike Strobel

Over the next two weeks, I want to discuss how we use isotopes to identify sources of water and for age-dating water. The term “isotopes” sounds very technical, but the concepts we will discuss really are quite simple.

I think isotopes offer some really cool science. I know that geeky scientists like me find strange things interesting, but after we discuss the topic, maybe you will agree with me.

First, let’s discuss the definition of isotopes. Everything in the world is made up of atoms. There are over 100 different types of atoms that occur naturally in the world. Each atom is made up of smaller components called protons, neutrons, and electrons. The combination of these smaller components is what makes atoms different.

For example, I think most people are aware that water is referred to H_2O. This means that water is made up of two hydrogen atoms and one oxygen atom. Every atom has its own weight, as determined by the number of protons and neutrons (electrons really don’t have much weight compared to the protons and neutrons). Hydrogen has one proton and one electron, so the weight is 1. Oxygen has eight protons, eight neutrons, and eight electrons, so its weight is 16.

This relationship of the number of protons and neutrons making up the atomic weight works for every atom and it’s what makes each type of atom different from other atoms. For example, gold has 79 protons and 79 neutrons, aluminum has 13 protons and 13 neutrons, etc. Of course, there are equal numbers of electrons, but because these don’t weigh much, we can ignore them in our discussion of atomic weight.

However, nature likes to throw curve balls. In many cases, atoms occur with additional neutrons. This makes these particular atoms heavier than those with equal numbers of protons and neutrons. Atoms with extra neutrons are called isotopes. In the case of hydrogen, there is an isotope with one proton and one neutron. This is called deuterium and it has a weight of 2. Oxygen has an isotope that has eight protons and 10 neutrons, which has a weight of 18. This doesn’t have a fancy name, rather is referred to as Oxygen-18. In nature, these isotopes of hydrogen and oxygen make up only a small fraction of all of the hydrogen and oxygen, but their occurrence is most important to scientists.

If all water in the hydrologic cycle contain hydrogen, deuterium, oxygen, and oxygen-18, including water held in clouds, in the ocean, in ground water, etc., then how these atoms get distributed becomes really important.

Here is an example. Clouds have water vapor made up of all four of these atoms. As clouds move inland from the oceans and get pushed up over mountain ranges, the clouds will begin to drop their moisture (which is why there is so much rain in Seattle west of the Cascade Mountains compared to dry Spokane east of the mountains). It seems logical that the heavier atoms (deuterium and oxygen-18) would fall out first and the lighter atoms would hang in there longer.

This is exactly what happens. Heavy isotopes of water tend to drop as rain and snow at lower altitudes and the lighter atoms get deposited further up in the mountains. The same works for temperature. The warmer the temperatures, the heavier the atoms the clouds can hold. If the atmosphere becomes cooled, the heavier atoms will fall out first. Not only do we see heavier atoms precipitated at lower elevations, but the same is generally true for lower latitudes (the precipitation has lighter isotopes with distance from the equator).

The way isotopes behave is really useful to hydrologists. If we look at the ratio of hydrogen to deuterium and the ratio of oxygen-16 to oxygen-18, we can use this to help identify where the ground water was recharged.

In the case of eastern Nevada, if we collected water from springs and compared it to precipitation samples in the area, we can use isotopes to tell us where the water generally recharged the ground water. For instance, if a spring has water with a hydrogen and oxygen ratio that was much lighter than the water collected from precipitation near the spring, we could conclude that the water feeding the spring came from a higher elevation (higher in the mountains). Likewise, in a large aquifer system, if the water in a well or spring was much lighter than local precipitation, it can be concluded that the recharge is not from local precipitation.

In many ways, isotopes of hydrogen and oxygen provide a “signature” to the ground water. Well or spring water sampled from different sites but with similar ratios may be from the same recharge area. Isotopes alone can’t definitely tell us this, but in combination with other tools, such as geochemistry, models, etc., we can make some interpretations about where the water was recharged.

Isotopes of hydrogen and oxygen also can be used to look at interpreting climate during the time when recharge occurred. For example, in many deep ground-water basins in Nevada, the water is lighter than present recharge. One conclusion might be that the water flowed in from higher elevations or latitudes, but another conclusion could be that the water was recharged many thousands of years ago during the Pleistocene (last Ice Age) when many basins in Nevada were covered with lakes. This cooler, wetter period in Nevada history may be observable in the isotopes in the ground water.

The science is complex and there are many other things that one must consider. For instance, isotopes in precipitation change with the seasons and winter snowfall typically is lighter than summer thunderstorms. However, this discussion gives a general idea of how the information can be used to understand ground-water flow.

We see that isotopes can tell us a lot about where water enters the system and how it varies with elevation and latitude. There are other isotopes that have use to hydrologists, but we'll leave those for future discussions.

Next week, we will explore unstable, or radioactive, isotopes. The interesting thing about radioactive isotopes is that they change over time, and so using these isotopes can offer a tool for actually age-dating waters (estimating the age of the water).

If you have questions about isotopes or any water topic, please contact me in care of the Ely Times or email me at mstrobel@usgs.gov.